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INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 7 : H04L 1/00, 5/02	A1	(11) International Publication Number: WO 00/65764 (43) International Publication Date: 2 November 2000 (02.11.00)

(21) International Application Number: PCT/US00/10809

(22) International Filing Date: 20 April 2000 (20.04.00)

(30) Priority Data:
09/301,484 28 April 1999 (28.04.99) US

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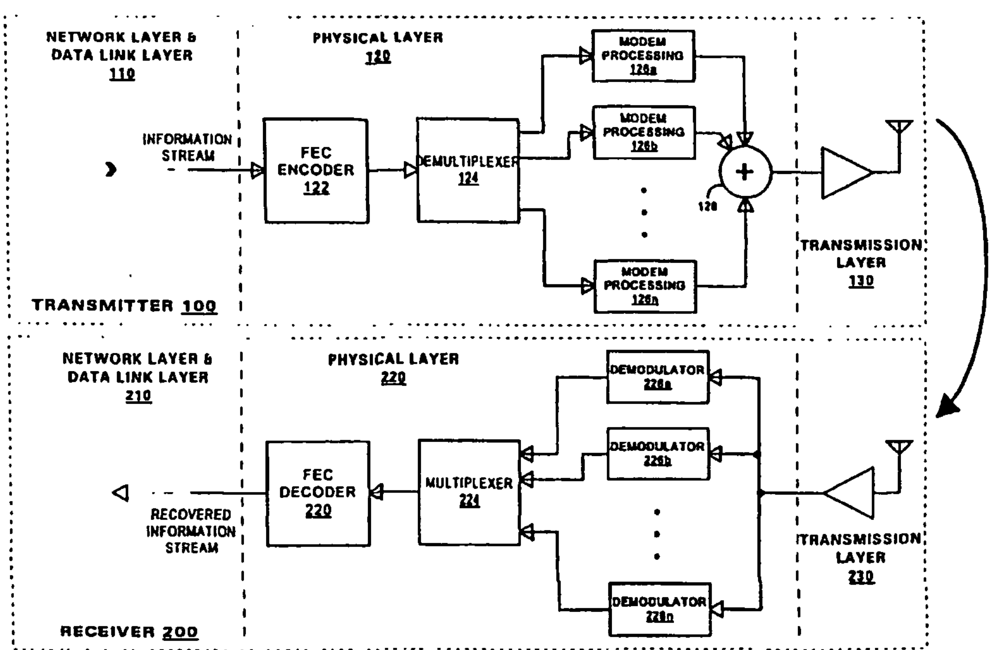
(81) Designated States: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CR, CU, CZ, DE, DK, DM, DZ, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, UZ, VN, YU, ZA, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

Published

With international search report.
Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.

(54) Title: FORWARD ERROR CORRECTION SCHEME IN A WIRELESS SYSTEM



(57) Abstract

A transmitter/receiver system for high data transfer in a wireless communication system includes a physical layer processor that comprises an FEC coder, a demultiplexer and a plurality of modem processors. The FEC coder applies error correction codes to the high data rate signal. Thereafter, the demultiplexer distributes portions of the coded high data rate signal to the modem processors. Each modem processor processes its respective portion of the coded signal for transmission in an independent channel.

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FORWARD ERROR CORRECTION SCHEME IN A WIRELESS SYSTEM

BACKGROUND

The present invention provides a low latency error correction mechanism for high data rate transmissions over multiple traffic channels in a wireless communication system.

It is known to include forward error correction ("FEC") coding and decoding to information signals that are to be transmitted over a wireless channel. Forward error correction, generally speaking, introduces predetermined redundancy into an information signal to permit a receiver to identify and perhaps correct errors that may have been introduced by a transmission medium. For example, the known IS-95 standard for code division multiple access cellular communication specifies a type of convolutional code for each traffic channel transmitted from base station to mobile station or vice versa.

Recently, it has been proposed to provide high data rate exchanges over a wireless communication system. Such high data rate exchanges may be used, for example, to facilitate data transfer for computing applications or for video conferencing applications. In one such proposal, a high rate data signal may be communicated to a receiver over a plurality of parallel traffic channels. For example, the recently proposed IS-95 B standard proposes use of parallel CDMA channels each having a data rate of 9.6 KB/s to provide a higher data rate communication. In such systems, a high rate data signal is demultiplexed into a plurality of lower rate data signals and each of these signals is processed in an independent traffic channel. Thus, each lower rate data signal has FEC applied to it.

Another example of a wireless CDMA system providing multiple parallel traffic channels for high data rate exchange may be found in the copending patent application "Protocol Conversion and Bandwidth Reduction Technique Providing Multiple nB+D ISDN Basic Rate Interface Links Over a Wireless Code Division Multiple Access Communication System," serial no. 09/030,049 filed February 24, 1998 the disclosure of which is incorporated herein.

Wireless communication channels are inherently "noisy" due to channel impairments caused by atmospheric conditions, multipath effects, co-channel interference and the like. Particularly if used for computing applications, where executable content may be expected to be exchanged over traffic channels, the need for powerful FEC techniques will continue to be prevalent.

Use of more powerful FEC techniques in such wireless systems may increase the latency of data requests. For example, the known turbo codes require large blocks of data to be received entirely by a decoder before decoding can begin. Latency refers generally to the delay that extends from the time a request for data is issued by a user and the time when data responsive to the request is presented to the user. FEC introduces decoding delays at a wireless receiver and, thus, contributes to latency.

There is a need in the art for a wireless communication system that provides high data rate exchange having high quality FEC with low latency.

SUMMARY

Embodiments of the present invention provide a transmitter/receiver system for high data transfer in a wireless communication system in which a physical layer processor comprises an FEC coder, a demultiplexer and a plurality of modem processors. The FEC coder applies error correction codes to the high data rate signal. Thereafter, the demultiplexer distributes portions of the coded high data rate signal to the modem processors. Each modem processor processes its respective portion of the coded signal for transmission in an independent channel.

BRIEF DESCRIPTION OF THE DRAWINGS

The Figure illustrates a transmitter and a receiver each constructed in accordance with embodiments of the present invention.

DETAILED DESCRIPTION

The present invention provides low latency forward error correction for a high data rate wireless transmission by applying forward error correction codes to data prior to multiplexing the data across a plurality of parallel fixed bandwidth traffic channels.

The Figure is a block diagram of a transmitter 100 and a receiver 200 each constructed according to embodiments of the present invention. The transmitter 100 and receiver 200 are illustrated as operating in a layered communication system that includes a transmission layer (110, 210), a physical layer (1120, 220) and higher layer communications such as network layers & data link layers (collectively labeled 130 & 230). As is known, in the transmission layer 110, a transmitter 100 performs carrier modulation, amplification and transmission upon digital data to be transmitted. Also as is known, in the transmission layer 210, a receiver 200 performs reception, amplification and carrier demodulation to obtain a recovered digital data signal. The higher layers 110, 210 of the communication system also may process an information signal as may be required for the application for which the present invention is to be used.

According to an embodiment of the present, the physical layer 120 of the transmitter 100 may be populated by an FEC coder 122, a demultiplexer 124 and a plurality of modem processors 126a-1 26n. The number of modem processors 126a-1 26n may vary and also may be determined by the quantity of data to be transmitted and the capacity of each of the traffic channels over which the data may be transmitted. The FEC coder 122 receives a source signal from a higher layer I 10 in the transmitter and enhances it with an error correction code. The enhanced information signal Is output from the FEC coder 122 to the demultiplexer 124. The multiplexer distributes the information signal to the modem processors 126a-126n. The modem processors I 26a-1 26n each format their respective portions of the enhanced signal for transmission. Outputs from the modem processors 126a-1 26n are summed by an adder 128 and delivered to the transmission layer 110.

At the receiver 200, the physical layer 220 performs processing that is the inverse of the processing that had been applied in the physical layer 120 of the

transmitter 100. The physical layer 220 may be populated by an FEC decoder 222, a demultiplexer 224 and a plurality of demodulators 226a-226n. There will be one demodulator 226a-226n for each of the traffic channels that had been allocated to carry the information signal. The recovered digital signal from the transmission layer 230 is input to each of the demodulators 226a-226n. Each demodulator 226a-226n outputs a recovered portion of the information signal. The demultiplexer 224 merges each of the recovered portions of the information signal into a unitary recovered information signal. The FEC decoder 222 performs error detection and correction using error correction codes that had been introduced by the FEC coder 122 in the transmitter 100. The FEC decoder 222 outputs a corrected information signal to the higher layers 210 of the receiver 200.

In a CDMA embodiment, which is shown in the Figure, a receiver 200 need not include an element corresponding to the adder 128 of the transmitter 100; the demodulators 226a226n each perform correlation. As is known, correlation permits a modem processor to discriminate a desired CDMA signal from other CDMA signals that may be present in an aggregate received signal. Thus, in the embodiment of the Figure, the demodulators 226a-226n identify and output respective portions of the recovered enhanced information signal.

According to an embodiment of the present invention, the FEC coder 122 and FEC decoder 222 may generate and decode iterative systematic nested codes, also known as "turbo" codes. These turbo codes provide an advantage in that the FEC decoding process may be repeated iteratively to improve the information signal recovered therefrom. Thus, the output of a first iteration may be reintroduced to the FEC decoding block (path not shown in the Figure) for subsequent iterations. The nature of the turbo codes generates improved corrected data at subsequent iterations.

The known turbo codes, however, introduce a predetermined amount of latency into the decoding process. Turbo codes operate on blocks of a predetermined size. For example, one turbo code being considered for a wireless communication system for computer network applications possesses a block size of 4,096 channel symbols. An FEC decoder 222 must decode an entire block before a recovered information signal becomes available for the block. This characteristic may be

contrasted with convolutional codes which are used in the known IS-95 standard for CDMA cellular communication; convolutional codes are characterized by relatively smaller latency for same-sized block (relative to turbo codes) because it is not necessary to receive an entire block before decoding may begin. It is believed that by distributing the FEC code among several parallel traffic channels as is shown in the Figure, the higher aggregate throughput of the traffic channels ameliorates the latency that would otherwise be introduced by the turbo code.

For high data rate applications using plural parallel traffic channels, it is believed that use of turbo codes achieves a higher figure of merit (lower E_b/N_0 than for convolutional codes. Using the example of a 4,096 channel symbol sized block and E_b/N_0 of 1.5 dB the turbo code provides a BER of 10^{-6}. By contrast, for voice systems requiring a less stringent 10^{-3} BER, a convolutional code requires an E_b/N_0 of 7 dB or more.

The techniques of the present invention find application in a variety of wireless communication systems including CDMA systems. Typically, in application, the base stations and subscriber stations of the wireless communication system will include functionality of both the transmitter and receiver of the Figure. That is, to provide two-way communication, a base station will include a transmitter portion 100 and a receiver portion 200. So, too, with the subscriber terminal. The base stations and subscriber terminals may but need not be configured to provide simultaneous fullduplex communication.

Typically, a base station of a wireless communication system transmits a plurality of data signals to a variety of subscribers simultaneously. According to an embodiment of the present invention, each base station may perform the techniques disclosed herein simultaneously on a number of high rate data signals. It is consistent with the spirit and scope of the present invention that each signal may have a data rate that is independent of the data rates of the other signals. Thus, in such a case, a base station may be configured to include its FEC coder/decoders 122, 222 and modem processor/demodulators 126a, 226a in a pooled configuration. Such an embodiment permits the base station to assign, for example, a variable number of modem processors 126a126n to a data signal depending upon the rate of the signal

to be transmitted. Similarly, by including a pool of FEC coders 122 (shown singly in FIG.1) in a base station, the base station may selectively enable FEC coders 122 as the base station receives new data signals to be transmitted to subscribers. Provision of base station processing components in a pooled arrangement is well-known.

Several embodiments of the present invention are specifically illustrated and described herein. However, it will be appreciated that modifications and variations of the present invention are covered by the above teachings and within the purview of the appended claims without departing from the spirit and intended scope of the invention.

CLAIMS

WE CLAIM:

1. In a CDMA transmitter, a physical layer processor, comprising:
an FEC coder,
a demultiplexer having an Input in communication with the FEC coder, and
a plurality of modem processors, each having an input in communication with the demultiplexer.

2. The CDMA transmitter of claim 1 provided in a base station of a CDMA communication system.

3. The CDMA transmitter of claim 1 provided in a subscriber station of a CDMA communication system.

4. The CDMA transmitter of claim 1, wherein the FEC coder operates according to an iterative systematic nested code.

5. The CDMA transmitter of claim 1, wherein the FEC coder operates according to a turbo product code.

6. The CDMA transmitter of claim 1, wherein the FEC coder according to a convolutional turbo code.

7. The CDMA transmitter of claim 1, wherein the physical layer processor further comprises an adder coupled to each of the modem processors and the transmitter further comprises a transmitter section having an input coupled to the adder.

8. In a CDMA receiver, a physical layer processor comprising:

a plurality of demodulators,

a multiplexer having inputs in communication with each of the demodulators, and

an FEC decoder having an input coupled to the multiplexer.

9. The CDMA receiver of claim 1 provided in a base station of a CDMA communication system.

10. The CDMA receiver of claim 1 provided in a subscriber station of a CDMA communication system.

11. The CDMA receiver of claim 1, wherein the FEC decoder operates according to an iterative systematic nested code.

12. The CDMA receiver of claim 1, wherein the FEC decoder operates according to a turbo product code.

13. The CDMA receiver of claim 1, wherein the FEC coder according to a convolutional turbo code.

14. A method of transmitting a high rate data signal over a wireless connection comprising:

enhancing the high rate date signal with a forward error correction code, distributing the enhanced data signal over a plurality of traffic channels, and

transmitting each of the traffic channels.

15. The method of claim 14, wherein the forward error correction code is an iterative systematic nested code.

16. A method of receiving a high rate data signal over a wireless communication channel, comprising:

receiving a plurality of lower rate data signals in traffic channels, merging the lower rate data signals into a unitary received data signal, performing error correction upon the unitary received data signal based upon a forward error correction code therein.

17. The method of claim 16, wherein the forward error correction code is an iterative systematic nested code.

18. In a transmitter, a physical layer processor, comprising:

an FEC coder,

a demultiplexer coupled at an input to the FEC coder, and

a plurality of modem processors each coupled at an input there of to the demultiplexer.

19. The transmitter of claim 18 provided in a base station of a communication system.

20. The transmitter of claim 18 provided in a subscriber station of a communication system.

21. The transmitter of claim 18, wherein the FEC coder operates according to an iterative systematic nested code.

22. The transmitter of claim 18, wherein the FEC coder operates according to a turbo product code.

23. The transmitter of claim 18, wherein the FEC coder according to a convolutional turbo code.

24. The transmitter of claim 18, wherein the physical layer processor further comprises an adder coupled to each of the modem processors and the transmitter further comprises a transmitter section having an input coupled to the adder.

25. In a receiver, a physical layer processor comprising:

a plurality of modem processors,

a multiplexer having inputs coupled to each of the modem processors, and

an FEC decoder having an input coupled to the multiplexer.

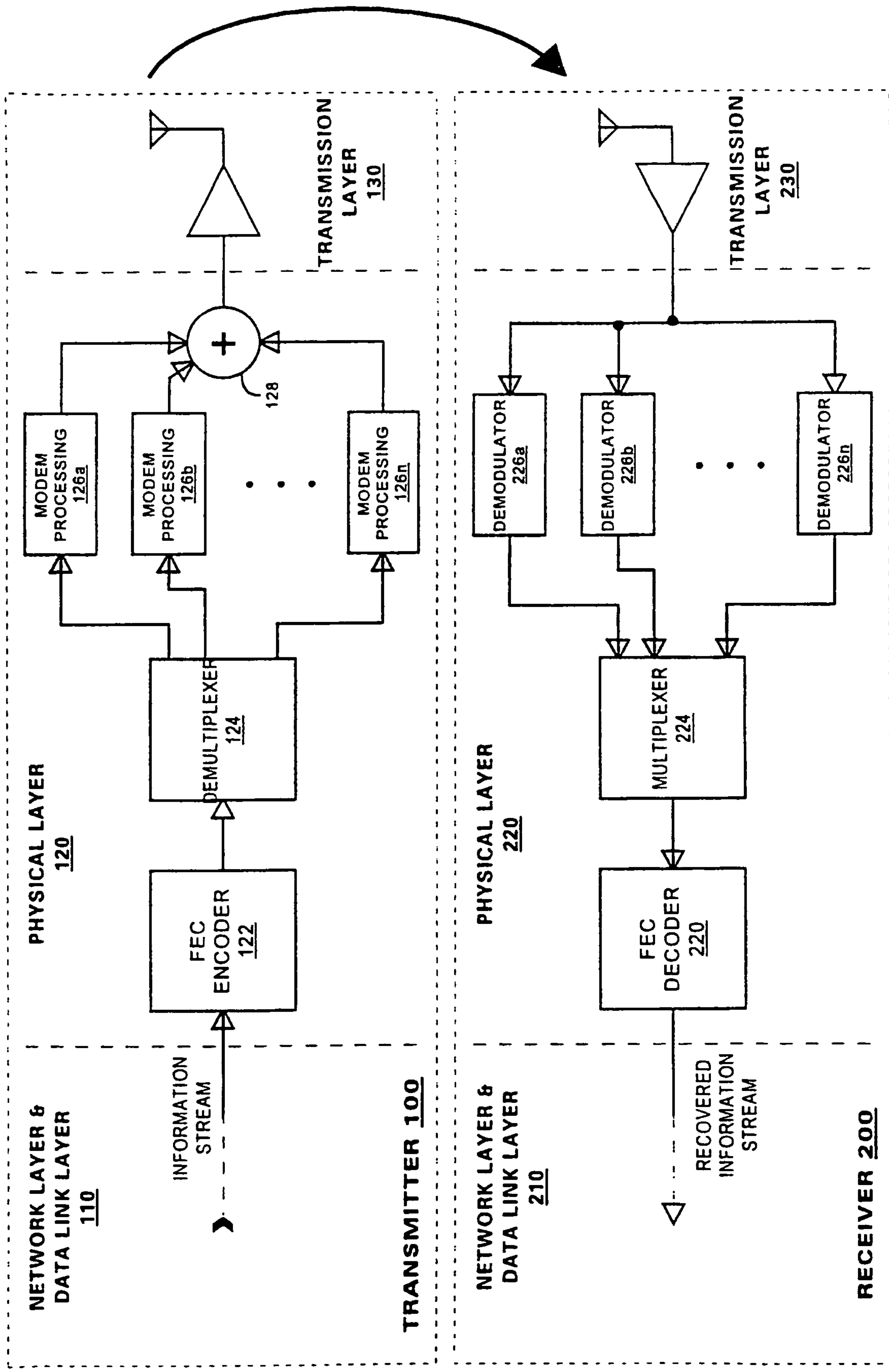
26. The receiver of claim 25 provided in a base station of a communication system.

27. The receiver of claim 25 provided in a subscriber station of a communication system.

28. The receiver of claim 25, wherein the FEC decoder operates according to an iterative systematic nested code.

29. The receiver of claim 25, wherein the FEC decoder operates according to a turbo product code.

30. The receiver of claim 25, wherein the FEC coder according to a convolutional turbo code.


TRANSMISSION LAYER 130
PHYSICAL LAYER 120
NETWORK LAYER & DATA LINK LAYER 110
INFORMATION STREAM
FEC ENCODER 122
DEMULTIPLEXER 124
MODEM PROCESSING 126a
MODEM PROCESSING 126b
MODEM PROCESSING 126n
128
TRANSMITTER 100
TRANSMISSION LAYER 230
PHYSICAL LAYER 220
NETWORK LAYER & DATA LINK LAYER 210
DEMODULATOR 226a
DEMODULATOR 226b
DEMODULATOR 226n
MULTIPLEXER 224
FEC DECODER 220
RECOVERED INFORMATION STREAM
RECEIVER 200

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 00/10809

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H04L1/00 H04L5/02

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Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H04L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

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WPI Data, PAJ, COMPENDEX, INSPEC

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 99 14878 A (QUALCOMM INC) 25 March 1999 (1999-03-25)	1-6, 8-23, 25-30
	abstract; figures 2,3	
Y	page 7, line 18 -page 8, line 2 page 9, line 11 - line 13	7,24
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X	WO 98 43373 A (BIGLOO AMIR ;FONG MO HAN (CA); LEE WOOKWON (CA); MATYAS ROBERT (CA) 1 October 1998 (1998-10-01) abstract; figure 1 page 3, line 13 - line 18 page 5, line 26 - line 31	1,4-6, 14,15, 18,21-23
A	page 9, line 9 - line 14	11-13, 17,28-30
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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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14 August 2000	21/08/2000

Name and mailing address of the ISA	Authorized officer
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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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INTERNATIONAL SEARCH REPORT

Information on patent family members

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